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Assessment of the Condition of Small Fish-bearing Streams in the Central Interior Plateau of British Columbia in Response to Riparian Practices Implemented under the Forest Practices Code

BRITISH COLUMBIA

Ministry of Forests Research Program

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ABSTRACT

The condition of small fish-bearing streams (Forest Practices Code class S4) in the central interior of British Columbia was assessed to determine the effects of riparian forest harvest practices implemented under the B.C. Forest Practices Code. The purpose of the survey was to determine:

1. How frequently are the different types of streamside harvesting practices implemented?
2. Do the different types of streamside harvesting practices meet the objectives of the *Riparian Management Area Guidebook*? and
3. Do the different types of streamside harvesting practices result in apparent impacts to fish habitat?

The survey investigated the extent of forest harvesting potentially affecting small fish-bearing streams, the prevalent riparian silviculture treatments and levels of tree retention, the evidence for stream channel disturbance after forest harvesting, the degree of shade loss over the stream, and the extent of windthrow and windthrow-related impacts to the stream.

The review of 2989 cutblocks harvested between 1997 and 1998 in six forest districts in the central interior plateau of British Columbia revealed that only 2.4% of these cutblocks contained a designated S4 fish stream or were immediately adjacent to one. A wide range of riparian silviculture treatments was implemented: 68% of these S4 streams had some type of unharvested riparian reserve, 10% were given partial-retention treatments, and 22% of riparian management areas were clearcut. The different riparian treatments are generally meeting the objectives of the Forest Practices Code *Riparian Management Area Guidebook*. Eight percent of the streams had a moderate level of stream channel disturbance due to harvesting or post-harvest windthrow. Additional potential impacts included high levels of shade loss (7% of the streams) and loss of streambank trees (3% of the streams). Windthrow was common in all treatment types, but rarely resulted in stream channel disturbance. Across the six districts, the overall impact to designated S4 fish stream channels and their fish habitats from harvest activities in 1997–1998 is considered low.

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Validation of existing forestry practices in British Columbia, particularly riparian practices around small fish-bearing streams, is a high priority for both provincial and federal resource agencies and the forest industry. Current Forest Practices Code (FPC) standards and guidelines allow for more flexibility for riparian management around smaller fish-bearing streams and those streams without fish than for larger fish-bearing ones.

For fish streams ≥ 1.5 m wide (classes S1, S2, and S3), FPC regulations require a Riparian Management Area (RMA) consisting of a Riparian Reserve Zone (RRZ) of specified width immediately adjacent to both sides of the stream, and an outer Riparian Management Zone (RMZ) that borders the reserve (Table 1).

TABLE 1 *Forest Practices Code RMA standards. Widths of reserve and management zones are slope distances measured from the streambank perpendicular to the channel. Riparian classes S1 to S4 are fish-bearing streams or streams in community watersheds. Classes S5 and S6 are streams without fish.*

Riparian class	Average channel width (m)	Reserve zone width (m)	Management zone width (m)	Total width of RMA (m)
S1	> 20	50	20	70
S2	> 5 to ≤ 20	30	20	50
S3	1.5 to ≤ 5	20	20	40
S4	< 1.5	0	30	30
S5	> 3	0	30	30
S6	≤ 3	0	20	20

In contrast to the larger fish streams, no riparian reserves are mandatory for fish-bearing streams < 1.5 m wide (class S4), or for streams without fish (classes S5 and S6)(Table 1). The RMA around these streams consists of a management zone only. Practices around these small streams are guided by objectives within the *Riparian Management Area Guidebook*, including recommendations for Best Management Practices (see Appendix 1). For example, practices around S4 fish streams in interior forest districts may vary from leaving riparian reserves ≥ 10 m wide to clearcutting with retention of non-merchantable trees and understory vegetation.

The *Riparian Management Area Guidebook* states that riparian management area objectives for streams are:

1. to minimize or prevent impacts of forest and range uses on stream channel dynamics, aquatic ecosystems, and water quality of all streams, lakes, and wetlands;
2. to minimize impacts of forest and range use on the diversity, productivity, and sustainability of wildlife habitat and vegetation where high wildlife values are present; and
3. to allow for forest and range use that is consistent with objectives 1 and 2, above.

To achieve these objectives where the RMA has only a management zone, the *Riparian Management Area Guidebook* recommends that forest practices

within the management zone should retain sufficient vegetation along streams to provide shade, reduce microclimate changes, maintain natural channel and bank stability, and, where specified, maintain important attributes for wildlife. For S4 fish-bearing streams in interior forest districts, a set of Best Management Practices (BMPs) is recommended that can help meet the riparian objectives (Appendix 1). However, a wide range of acceptable BMPs is possible for any site depending upon windthrow hazard. Therefore, this study focused on the degree to which riparian silviculture practices met the objectives of the *Riparian Management Area Guidebook*, rather than on the implementation of BMPs.

After a period of transition, the B.C. Forest Practices Code riparian provisions came into full effect on December 15, 1995. Since that time, assessments of the effectiveness of the Code's riparian standards and guidelines for protecting streams have been limited both geographically and in technical detail. Therefore, resource managers are interested in determining whether the Code is effective in achieving its riparian management objectives, especially for streams where riparian reserves are not mandatory. Concerns have been expressed about the possibility of harmful alterations to fish habitat in small fish-bearing streams (S4) and in direct tributaries (S5 and S6) to fish-bearing waters as a result of removal of riparian trees during forest harvesting. Particular concern exists in regard to possible short-term and long-term effects on streams where RMAs are clearcut with minimal post-harvest retention of trees.

This study was undertaken to determine how frequently each type of riparian practice is implemented in different regions of the province, and whether these practices result in stream channel and riparian conditions that are consistent with the objectives of the Forest Practices Code as described in the *Riparian Management Area Guidebook*.

1.1 Study Goals and Scope

The purpose of this investigation was to examine cutblocks harvested in the central interior according to Silviculture Prescriptions (SPs) approved under full FPC standards and guidelines to answer the following questions:

1. How frequently are the different types of streamside harvesting practices implemented?
2. Do the different types of streamside harvesting practices meet the objectives of the *Riparian Management Area Guidebook*? and
3. Do the different types of streamside harvesting practices result in apparent impacts to fish habitat?

1.2 Cutblock and Stream Selection

Cutblocks reviewed in this survey were limited to those based on SPs approved after January 1, 1996 to ensure that SPs were prepared and forest practices conducted under full knowledge of *Riparian Management Area Guidebook* principles and objectives. Additionally, cutblocks selected were those harvested no later than the end of 1998, to ensure that all streams to be inspected in the field were exposed to at least 2 years of post-harvest climatic conditions (e.g., wind and rain storms, floods, and other natural disturbance agents).

The streams identified for field inspection were those designated as S4 fish streams that were located within or immediately adjacent to the cutblocks, and any non–fish-bearing streams (i.e., S6s) directly tributary to these S4s.

Cutblocks known to be in community watersheds were not included within this survey, because the management objectives for community watershed streams differ from those of streams managed specifically for their fish habitats. All streams in community watersheds are classified S1 to S4 based on channel width alone; that is, without regard to either their channel gradient or fish-bearing status. Some of these streams may have channel gradients > 20%. Outside of community watersheds, these steep streams that are not already known to contain fish can be deemed under the FPC to be non–fish-bearing and classified either as S5 or S6 without the need of an inventory to confirm fish absence. Therefore, a stream classified as S6 in an area outside of a community watershed might be classified as S4 or S3 within a community watershed. These complications were avoided by limiting this study to cutblocks and streams outside of community watersheds.

1.3 Riparian Silviculture Treatments

Riparian silviculture treatments possible for interior S4 fish streams can reflect a wide range of vegetation retention, spanning (1) clearcutting, (2) retention of non-merchantable trees, (3) partial retention of merchantable trees, and (4) full-retention riparian buffers 10 m wide or wider. This investigation sought to categorize the common types of riparian treatments as specified in SPs for the study area, and to visit as many sites as possible to document the actual levels of riparian retention implemented in the field within each identified riparian treatment category.

1.4 Evaluation of Riparian Management Effectiveness

Assessments of the effectiveness of each riparian retention strategy relative to *Riparian Management Area Guidebook* objectives focused primarily upon stream channel and aquatic habitat conditions. Evaluations of the effectiveness of riparian retention for maintaining local terrestrial wildlife values and biological diversity (e.g., by incorporating wildlife tree patches within RMAs) were not possible for several reasons. In particular, knowledge of the relationships between small-stream riparian areas and wildlife is incomplete and requires substantial research to answer basic questions. Riparian wildlife evaluations were thus beyond the scope of this study.

This investigation did not consider harvesting costs or economics of various harvesting practices, but was focused entirely on assessments of stream channel and riparian conditions, and on any physical and biological changes observable that could be attributed to riparian practices. The rationale for the forestry prescriptions and practices was not under question.

1.5 Short-term versus Long-term Impacts

This investigation documented the level of observable disturbances to stream channels, streambanks, and fish habitats 2–3 years after forest harvesting. Therefore, this report is primarily a summary of the short-term environmental effects of the application of FPC riparian standards and guidelines. For some parameters, the existing condition of the channels and adjacent riparian areas is used to forecast the likelihood of long-term disturbance to stream channels and fish habitats. However, there are strict limitations to these projections because they are not possible for several attributes. For example, it is difficult to interpret observed levels of riparian tree retention in the field with the minimum retention needed to satisfy long-term large woody debris (LWD) requirements for small stream channels because these minima have never been established scientifically, and are unknown.

For the population of S4 fish streams examined in this investigation, some general inferences can be made in regard to overall levels of impact resulting from FPC riparian management by considering their frequency across the

landscape, the levels of impact on these channels from all causes, and the likelihood of the transmission of these impacts downstream. However, the question of the cumulative effects of riparian management along S4 fish streams and their direct tributaries cannot be fully addressed within the scope of this study. Cumulative effects include all human-related environmental alterations within a watershed, both past and current, and may include other activities and developments related to forestry, roads, agriculture, recreation, mining, and so forth.

1.6 Study Area

Geographic coverage was limited to the following six forest districts in the central and southern interior: Merritt, Kamloops, Salmon Arm, Clearwater, 100 Mile House, and Williams Lake. The interior Fraser Plateau region covered by these spatially contiguous districts represented a geographic area with broadly similar topography, climate, and forest characteristics (Photo 1). The area is primarily within a snow-dominated hydrologic regime represented by the Interior Douglas-fir (IDF) and Montane Spruce (MS) biogeoclimatic zones with the Engelmann Spruce – Subalpine Fir (ESSF) zone at higher elevations. This area, part of the Fraser River drainage, also contains a diversity of fish, with highly valued populations of resident and anadromous fish.

Conclusions from this study are limited to the geographic area covered. The findings from this initial effort will guide the decision to conduct other SP reviews and field inspections elsewhere in the British Columbia interior and the coast.

PHOTO 1 *The study area was the central interior plateau, a flat to gently rolling terrain with numerous lakes, wetlands, and low-gradient streams.*

2 METHODS

The steps for this survey were:

1. review all Silviculture Prescriptions on file in the six district offices and identify all SPs that fit the selection criteria of full-Code forestry practices and harvest dates within 1997 and 1998;
2. select those SPs that included at least one designated S4 fish stream;
3. identify generalized riparian treatment (silviculture) categories specified in the SPs;
4. visit the designated S4 fish streams and any non–fish-bearing streams directly tributary to them within each of these treatment categories, and record
   (i) the level of vegetation retention,
   (ii) the extent and level of impact of observable disturbances to stream channels and banks,
   (iii) the likely cause of the disturbances observed,
   (iv) the extent of windthrow and windthrow-related channel disturbance,
   (v) the extent of shade loss,
   (vi) whether the objectives of the *Riparian Management Area Guidebook* were achieved, and
   (vii) any apparent impacts to fish habitat; and
5. describe and categorize the riparian retention strategies implemented in the field, and summarize observations of stream channel and riparian conditions for each.

Ultimately, this study sought to determine the effects of existing Forest Practices Code riparian practices on fish habitats. The assessment of fish habitat alteration was not made directly. Instead, the effects of riparian treatments upon fish habitat were determined by inference from the observations made on the physical state of stream channels and banks, the loss of streamside trees, and the loss of riparian shade. For example, riparian shade loss was used as a surrogate for potential changes to seasonal water temperatures and organic (leaf) litter input for the stream ecosystem. Given the time of year (October) and the short-duration design of the field study, no systematic temperature monitoring was possible, and no in-stream biological assessments were made.

For the purposes of this review, it was assumed that the designated S4 fish streams were fish-bearing; however, the true fish-bearing status of many of the streams is unknown. Fish inventories were not undertaken to confirm the fish-bearing status of the study reaches or to obtain quantitative information on the status of any populations present.

Fish population studies were not performed because data from a single survey are severely limited in their utility for a number of reasons. For example, no pre-harvest baseline information was available to illustrate fish population trends and range of natural variability. Study reaches were widely dispersed across a large geographic area and varied greatly in physical attributes, including gradient, elevation, aspect, drainage connectivity (fish barriers, etc.), and other factors that (1) result in a broad range of fish-habitat capability across sites, (2) make between-site comparisons problematic, and (3) have influences on fish populations that would obscure the effects due to riparian forestry practices and management.

2.1 Field Procedures

A crew of four professionals (one representative each from the B.C. Ministry of Environment, Lands and Parks, the B.C. Ministry of Forests, and the Federal Department of Fisheries and Oceans, and a consultant representing the Interior Lumber Manufacturers Association) visited each site. Team members were hydrologists or habitat biologists experienced in stream channel and fish habitat assessment.

Site access was by helicopter. Cutblocks and streams were surveyed and photographed from the air. Representative stream reaches were identified from the helicopter.

A representative 100-m section of the S4 fish stream was selected for detailed survey. This sample section was typically 25–50% of the total stream length through the cutblock. The selected section was representative of the channel type, the surrounding topography, and the stand treatment type. Where two distinct channel types were in or adjacent to the cutblock, or where two treatment types occurred, then a second 100-m section was selected and a separate field form completed for that section. At the end of any 100-m survey, if the study team felt that the results were inconclusive, then a second or third section was evaluated.

At the end of each stream survey, each member of the survey crew reviewed and agreed on all observations made on the field form and arrived at a consensus on stream channel and aquatic habitat impact.

2.2 Observations

All parameters measured or estimated are detailed in Appendix 2. The following information was collected:

Stream: terrain type, flow stage, channel type, and stream dimension (channel width and depth)

Fish: basis of stream classification (fish presence confirmed or by using the < 20% gradient default for fish-bearing status)

Sediment: sources

Stream channel disturbance: disturbance type, length of disturbance, and level of impact

Riparian: harvest method, silvicultural system, tree count (in 50-m^2 circular plots) by size class and whether deciduous or coniferous (note: no differentiation was made between merchantable and non-merchantable trees), estimated percent tree retention (in four bands from the channel margin to the outer edge of the 30-m RMA), windthrow (throughout the RMA), and shading (canopy and total).

Metred "hip chain" was used to survey the 100-m study sections and identify the location of observations such as the type and length of stream channel disturbances. Counts of coniferous and deciduous trees by size class were made within paired circular plots (each of 3.99-m radius and 50-m^2 area) located adjacent to the channel margin on either side of the stream. The plots were located at metres 25 and 75 along each 100-m study section.

Metre tapes were used at each site to divide the 30-m-wide RMA into the following bands to estimate the percent tree retention in each band and overall: 0 (channel margin) –5 m, 5–10 m, 10–20 m, and 20–30 m. Trees retained were divided into three size classes according to trunk diameter at breast height (dbh): (1) < 15 cm dbh, (2) 15–30 cm dbh, and (3) > 30 cm dbh. All trees ≥ 15 cm dbh were considered to be suitable as functional LWD in small streams < 1.5 m wide. When woody stems of this diameter enter these channels, they may occupy up to two-thirds or more of the bankfull channel

depth, and are capable of retaining alluvial sediment, moderating water velocities, providing structural complexity, and providing overhead shelter for fish.

2.3 Impact Assessment

The impact assessment focused on four parameters: length and degree of stream channel disturbance, shade loss, windthrow, and loss of streambank trees. In the series of graphs that follows this section, each of these parameters is plotted by frequency of impact occurrence against riparian treatment type. The survey results focus only on the harvested side of the stream in determining tree retention levels. Sample size varies slightly between some graphs because some information was not collected at all sites.

The four impact indices were:

1. Length and degree of stream channel disturbance
2. Shade loss
3. Windthrow
4. Loss of streambank trees.

1. Length and degree of stream channel disturbance

Channel impact is defined as the "percentage of the length of the stream channel with moderate or high levels of observed stream channel disturbance." Stream channel disturbance is defined by the occurrence of one or more of the following channel disturbance indicators:

Channel Disturbance Codes

Bed disturbance

C1 Mid-channel bars, indicating sediment accumulation
C2 Frequent fresh, even-aged, unvegetated bars
C3 Homogeneous textures (fine or coarse) compared to natural template of heterogeneous sediment size distribution
C4 Bar elevation higher than banks
C5 Pool area decreased due to riffle crest erosion or due to depositional infilling
C6 Pools infilled with sand or gravel
C7 Mechanical scouring of the bed as a result of yarding
C8 Sluiced-out channel not attributable to a mass wasting event

Bank disturbance

B1 Recently disturbed banks due to mechanical disturbance
B2 Banks primarily evenly sloping as the channel erodes into the bed
B3 Extensive bank erosion (absence of undercut banks) as coarse sediment is deposited overbank
B4 Frequent fresh sediment sources along banks

In-stream wood characteristics

D1 Debris jams infrequent and large compared to natural templates of frequent and small
D2 Debris jams young and even-aged compared to natural template of distributed age classes

D3 Frequent non-functional woody debris (parallel to flow or elevated above the banks)
D4 Frequent accumulations of broken wood and slash; non-functional or in jams
D5 Older LWD buried beneath recent sediment

All channel impacts were the result of disturbances at the site. There was no need to separate out channel disturbance that was a result of disturbance upstream, because all of the streams have low downstream transport capacity.

For each disturbance type, the level of the disturbance was ranked as nil, low, moderate, or high. The length of the channel disturbance was also recorded. These disturbance classes were strictly for rating the physical disturbance of the stream channel and did not directly infer a similar level of fish habitat disturbance.

The Channel Impact Value (CIV) was calculated from the total length of the channel with moderate or high disturbance, according to the following table:

	No impact	**Low impact**				**Moderate impact**			**High impact**		
CIV	**0**	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	**0.9**	**1.0**
Percent of channel with moderate or high disturbance	0	0.5	1	2	3	6	10	15	20	50	90

Numerical ratings of CIV (0–1.0) allowed a single rating to be calculated where more than one reach was surveyed.

An Overall Channel Assessment Rating (OCAR) was then assigned by using mainly the CIV but allowed the group, by consensus, to adjust the rating based on other information. For example, the CIV is based solely on the length of moderate and high channel disturbance, whereas the channel may also have some length of low-impact disturbance in addition to the moderate and high. This information might elevate the final OCAR score above that indicated by the CIV.

2. Shade loss

Stream shade loss was estimated in categories of the original (pre-harvest) shade levels, based on comparisons with unharvested reaches. Two visual estimates were made:

- loss of original canopy shade; that is, the forest crown shade provided by both coniferous and deciduous trees, and
- loss of total shade; that is, the canopy shade plus shade provided by understory vegetation and topography.

Estimates of the percentage shade loss for each category are as follows:

Shade loss category	Estimated percent of shade loss
Nil	0–10
Low	10–40
Moderate	40–70
High	> 70

3. Windthrow

Windthrow was rated for the entire 30-m-wide RMA of the sampled reach by counting all windthrown trees or by estimating the categories of low, moderate, or high windthrow according to the following table:

Windthrow rating	No. of windthrown trees/100 m
Nil	≤ 2
Low	3–15
Moderate	16–30
High	> 30

This windthrow rating indicated the amount of windthrow in the RMA, but may or may not have constituted a hazard to the stream channel. The stream channel impact was determined separately by measuring:

- all channel disturbances caused by windthrown trees that entered or crossed the stream channel; and
- all root soil scars of windthrown trees that were exposed to the stream channel. The level of stream channel disturbance associated with windthrow was determined from the CIV index described above.

4. Loss of streambank trees

A streambank tree has at least some portion of its root system embedded within the substrate materials that constitute the matrix of the streambank. The base of a streambank tree might thus be located immediately adjacent to the channel margin, or, as in the case of some larger trees, a metre or more from the channel. Streambank trees contribute to bank stability, reduced erosion rates, the structure for overhanging banks (an important element of fish habitat), and fish cover. Streambank tree loss was scaled according to the following table; however, because of the uncertainties of what constitutes a future impact, the categories should not be interpreted as impact classes.

Streambank tree loss	Number of streambank trees harvested/100 m
Nil	0
Low	1–6
Moderate	6–12
High	≥ 13

3.1 Riparian Silviculture Treatments

Two of the objectives of this study are to determine the extent of different riparian harvesting treatments and to document the potential risks to fish habitat associated with each treatment type. Five types of riparian silviculture treatment were identified for S4 fish streams from the SP review and confirmed in the field. These treatments spanned the range of riparian retention from clearcuts to full-retention buffers (see Introduction). In this report, riparian buffers of full tree retention are termed "reserves." (It is recognized that these "reserves" do not have the legal connotation of "reserve" described in the FPC.)

Three of the five treatments incorporated buffer strips of trees into a riparian reserve. The two other silviculture treatments were categorized as partial retention and clearcut.

A *boundary reserve* forms one of the boundaries of the cutblock. This is a variable-width reserve ranging from more than 10 m wide up to 50 m wide (typically 20–30 m wide). The outer boundary of the reserve typically follows a topographic or vegetation break. In the districts covered by this survey, a common management technique is to locate the cutblock so that the falling boundary is partly or wholly outside of the 30-m RMA of the stream (Photo 2). Boundary reserves were thus identified as a valid riparian management treatment.

PHOTO 2 *A boundary reserve. The edge of the reserve follows a topographic or vegetation break and the stream is typically 20–30 m from the cutblock edge.*

A *fixed-width* reserve is an unharvested strip of trees typically about 10 m wide along the channel margin. Usually, the reserve is within the cutblock boundary (Photos 3a, b).

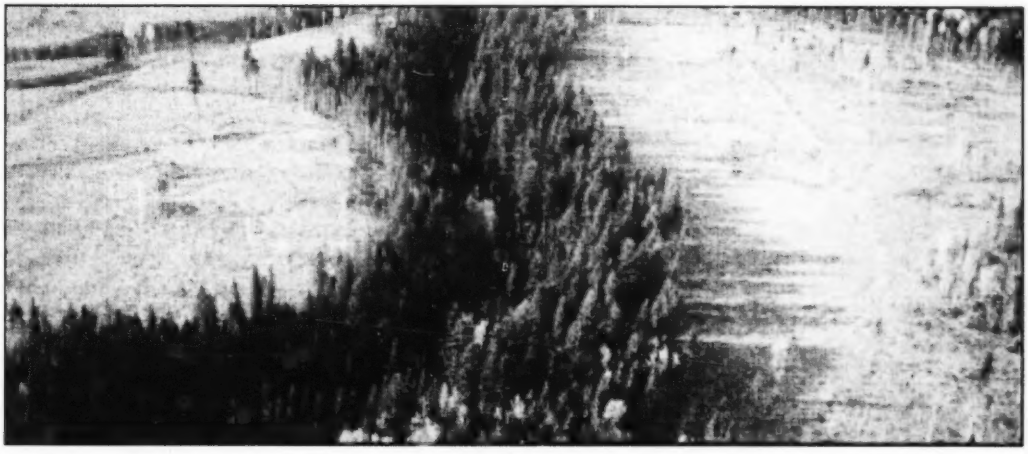

PHOTO 3a *Example of a fixed-width reserve. The reserve is 10 m wide throughout its length.*

PHOTO 3b *Example of a fixed-width reserve 10 m wide.*

A *variable-width reserve* is a strip of trees retained along the channel margin that varies from 0 to 10 m wide. Harvesting may occur to the streambank in some locations (Photo 4).

A *partial-retention treatment* is the retention of single trees or tree patches in a variety of patterns and combinations of deciduous and coniferous species within the 30-m RMA of the stream, but where a reserve is absent (Photos 5a, b).

A *clearcut treatment* is the harvest of all merchantable coniferous trees, but may include the retention of scattered deciduous, non-merchantable conifers and understory vegetation, typically within 5 m of the streambank (Photo 6a). Amount retained varied from virtually no trees (Photo 6b) to retention of up to 60 large (non-merchantable) trees per 100 m of channel (Photo 6c).

The five generalized riparian treatment categories were readily distinguishable in the field despite variations in the distribution of retained trees both immediately adjacent to the stream and within the rest of the 30-m RMA that occurred within the intermediate-retention treatments such as partial retention and variable reserve.

Variations in the amount and distribution of riparian retention within any treatment category could be due to topography, a change in vegetation, or the incorporation of a wildlife tree patch (WTP) into the RMA (Photo 4). Streams with deeply incised channels exemplify topographic influences upon riparian management. When an S4 fish stream channel occurred within a ravine or canyon, full riparian retention from the channel margin up to the top of the canyon slope (inner gorge) was observed (Photo 7).

PHOTO 4 *Variable-width reserve where a wildlife tree patch (lower left) has been incorporated into the reserve.*

PHOTO 5a *A partial-retention RMA and cutblock. Selection or group selection harvesting of the RMA.*

PHOTO 5b *Example of a partial-retention RMA (centre-left).*

PHOTO 6a *Typical clearcut riparian treatment. Most clearcut blocks had retention of non-merchantable and deciduous components within 5 m of the stream.*

PHOTO 6b *Clearcut treatment with virtually no tree retention in the RMA. This end of the clearcut treatment range was not often observed.*

PHOTO 6C *Clearcut riparian treatment with retention of up to 60 deciduous trees (e.g., aspen) per 100 m of channel.*

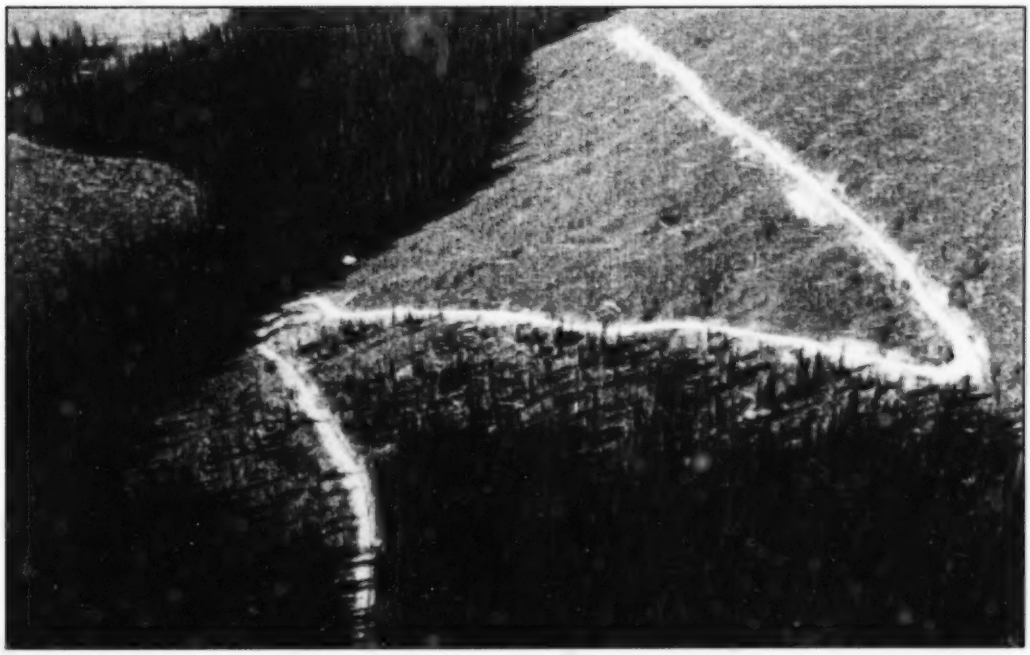

PHOTO 7 *Topograpic influence upon riparian retention included canyons or ravines where full retention of trees was observed from the channel margin to the top of the gorge.*

3.2 Summary of Observations

The Silviculture Prescription review across six forest districts identified 2989 SPs approved after January 1, 1996 under full FPC standards and guidelines, and for which cutblocks were harvested either in 1997 or 1998.

Only 81 cutblocks, representing 2.7% of the total, contained designated S4 fish streams within or immediately adjacent to (within 50 m of) the cutblock boundaries (Figure 1). There were a total of 86 designated S4 fish streams in the 81 cutblocks.

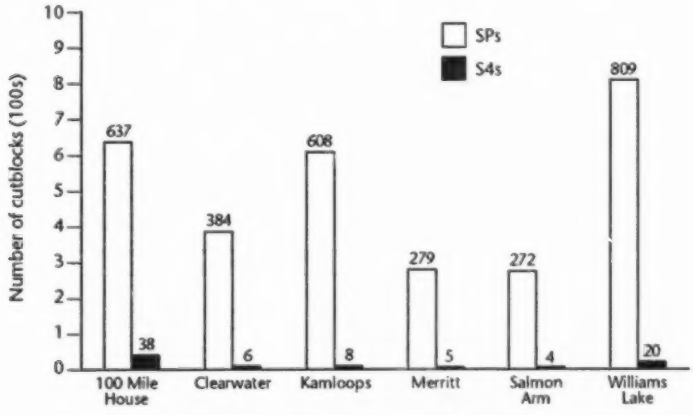

FIGURE 1 *The total number of cutblocks harvested in each district in 1996–1998 and the number of cutblocks containing or adjacent to streams designated as S4 fish streams.*

This percentage varied among districts but never exceeded 6%. The percentage of cutblocks with designated S4s was the least in Kamloops District (1.3%), varied between 1.5 and 1.8% in Salmon Arm, Clearwater, and Merritt districts, approximated the overall mean in Williams Lake District (2.5%), and peaked at 6% in 100 Mile House District.

The 81 SPs that met the survey criteria had 86 designated S4 fish streams mapped within or adjacent to the cutblock boundaries (Figure 2). However, in the field, only 72 of the mapped streams met the definition of a stream as defined in the FPC. Fourteen watercourses, making up 16% of the total number of mapped S4s, were found not to meet the Code definition of a stream. These non-stream sites were most commonly seeps or moist, vegetated draws with soil horizons and no channel bed present. In other cases, non-stream sites were fragmented, discontinuous channels with discontinuous banks. Because they were not streams, they were also incorrectly identified as fish streams. Field assessments were not performed at the 14 non-stream sites; therefore, these locations were not included in any subsequent analyses.

Only 11 streams, or about 13% of the total (86), had been identified as fish-bearing by an inventory conducted in the field. All of the other streams mapped as S4s were designated as fish-bearing by use of the < 20% channel gradient default as specified by the fish-stream definition in the FPC regulations.

Class S6, non–fish-bearing streams that were direct tributaries to the designated S4s were virtually absent: only five were encountered among the 72 designated S4s that were valid Code streams. Four of the five S6s occurred in

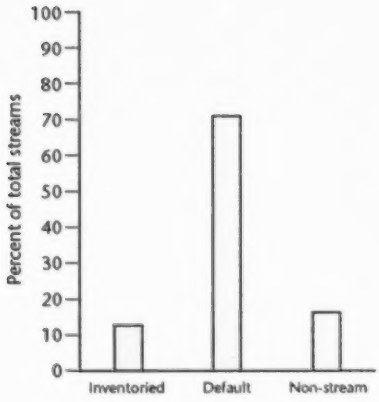

FIGURE 2 *Fish-stream identification and stream classifications for watercourses inspected in the field.*

unharvested areas and one occurred within the forested area along the boundary of a cutblock. No channel disturbances were observed in any of these streams. This study was not able to address issues of S6 riparian management and its effects upon fish habitats because of the very small number of direct-tributary S6s and the lack of forest harvesting around them. The lack of designated S6 streams might be partly explained by the stream classification methodology commonly employed for the cutblocks in question.

The true fish-bearing status of most of the study streams is unknown because 87% were designated as S4s on the basis of channel gradient alone. Many of these streams were the low-order headwaters of greater drainage basins. The fish-bearing status of these streams is questionable for several reasons. Many streams were in high-elevation sites remote from the nearest known fish-bearing waters. Others were located upslope of significant topographic breaks, and flows were seasonal. Additionally, a small number (five streams) were < 0.5 m wide, where fish habitat availability is very limited. It is possible that some of the streams designated and managed as S4s were non–fish-bearing (S6) streams tributary to fish streams downslope of the cutblocks.

Channel widths were determined for 59 of the 72 valid streams initially selected for field assessment (Figure 3). (For the remaining 13 streams, channel width was not measured, but was only estimated.) Among the measured streams, five were > 1.5 m wide and thus were considered class S3 fish streams rather than S4 fish streams (by channel gradient default). These tentative S3s made up about 8.5% of the sample measured for channel width. The remainder of the sample (91.5%) consisted of streams within the class S4 width category. Forty-nine of these were > 0.5 m wide and were nearly equally divided between the 0.5–1.0 m (25) and > 1.0–1.5 m (24) width categories. Only five streams, comprising 9.2% of all S4s, were less than 0.5 m wide.

Five categories of riparian retention were identified within the population of 72 streams selected for field inspection (Figure 4). A wide variety of riparian retention was thus implemented across the six forest districts. Sixty-eight percent of RMAs incorporated riparian trees into one of three types of streamside reserve. Twenty-two RMAs (30.5% of the total) were in the boundary reserve category. Thirteen RMAs (18.1% of the total) contained

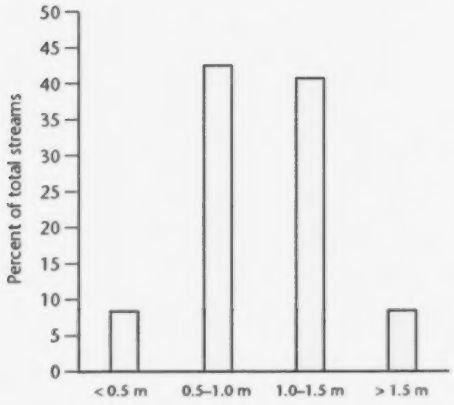

FIGURE 3 *Channel width categories within the population of streams inspected.*

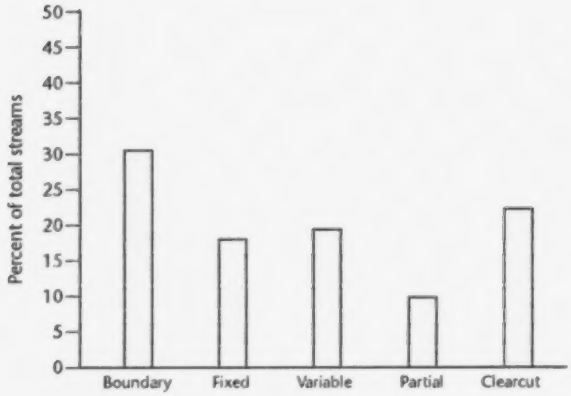

FIGURE 4 *Types of riparian silviculture treatments implemented. N = 72 streams.*

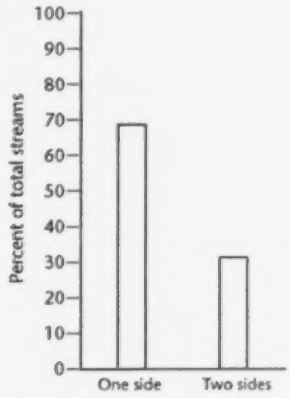

FIGURE 5 *One side or both sides of the RMA harvested.*

fixed-width reserves. Fourteen variable-width reserves made up an additional 19.4% of the total population. Seven RMAs (9.7%) were placed into a partial-retention category. Finally, 16 streams, forming 22.2% of the total, had RMAs that were clearcut.

A wide variety of riparian retention was implemented across the six forest districts, with 68% of RMAs incorporating riparian trees into one of three types of streamside reserve. The boundary reserve strategy was the most commonly implemented practice. The fixed-width reserve, variable-reserve, and clearcut practices were implemented in roughly equal frequencies, each approximating 20% of all retention strategies.

A stream may have harvesting along one side or both sides. The most common occurrence among the sites was harvesting on one side only (68%) (Figure 5). Two sides harvested was only one-half as common. Where two-sided harvesting occurred, the same riparian treatment almost invariably was used on both sides of the stream.

Figure 6a graphs the average percentage of tree retention as visually estimated within bands extending from the streambank (0- to 5-m band)

sequentially through the 5- to 10-m, 10- to 20-m, and 20- to 30-m bands to the outer margin of the RMA.

Boundary reserves had virtually 100% retention in each of the first three bands adjacent to the stream channel, and 80% retention in the outermost band. Fixed-width reserves have > 90% retention in the first two bands and about 37% retention in the third band. Variable-width reserves retained 80% of all trees within the innermost 5-m band, but only 46% in the second band. Average retention in the partial-cut treatment was 71% in the innermost 5-m band and ranged from approximately 23 to 53% in the three outer bands. Clearcut treatments had 22% retention within 5 m of the stream, 12% retention in the 5- to 10-m band, 3% in the third band, and < 1% in the outermost band from the stream.

Figure 6b is similar to Figure 6a, except that the bars now illustrate the cumulative average tree retention measured from the streambank across the

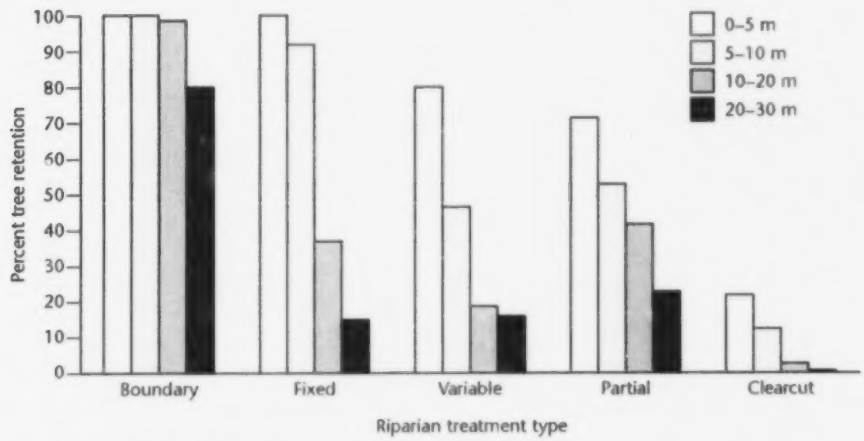

FIGURE 6a *Average tree retention across the RMA in 5- to 10-m bands by riparian treatment type.*

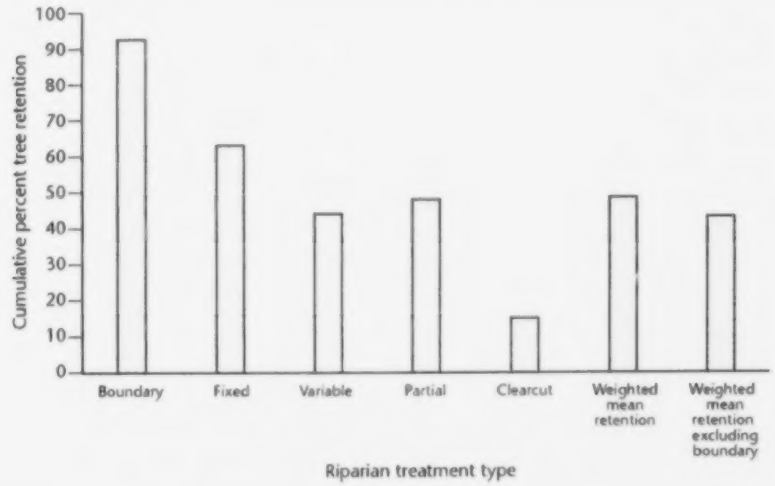

FIGURE 6b *Average cumulative tree retention (0–30 m) across the RMA by riparian treatment type.*

entire 30-m-wide RMA. It is important to note that these retention estimates include both merchantable and non-merchantable trees.

This graph shows that the average tree retention within the 30-m RMA varied with riparian treatment type from a low of 15% for clearcuts to 90% for boundary reserves. Average cumulative tree retention weighted for all treatment types is 49% for the entire 30-m-wide RMA. When boundary reserve treatments are excluded from the analysis, the average cumulative retention is 43%.

The *Riparian Management Area Guidebook* recommends, in terms of tree basal area, a 25% maximum overall riparian retention across all S4 fish streams within a forest development plan (as a target for balancing timber supply impact against retention). Riparian retention was presently estimated from tree count data and not from basal area calculations. Therefore, it is difficult to directly compare overall retention observed in this study against the *Riparian Management Area Guidebook* recommendation. However, given the observations that 68% of the study streams were provided with some form of riparian reserve, and that more than 30% of the RMAs had reserves from > 10 to 50 m wide, it appears that the guidebook-recommended Best Management Practice for retention around S4 fish streams was substantially exceeded across the six forest districts.

The overall level of tree retention in the innermost 10 m of the harvested side of the RMA, averaged over all treatment types, ranged from 47 to 83% for different size classes of S4 fish stream (Figure 7). Streams more than 0.5 m wide had a statistically similar retention of riparian trees (i.e., 70–80%) within the inner 10 m, regardless of stream width class. In contrast, streams less than 0.5 m wide had, on average, a lower level of retention (47%). This difference was statistically significant at the 95% confidence level, and indicates that very small streams (< 0.5 m wide) received less riparian retention than the larger S4 fish streams.

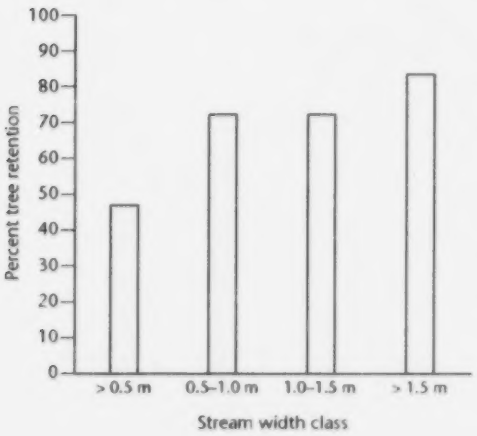

FIGURE 7 *Average tree retention in the innermost 10 m of the RMA by stream width class.*

Trees with a minimum dbh of 15 cm were considered to be fully suitable as functional LWD in small streams < 1.5 m wide (see Methods). Therefore, trees that are presently ≥ 15 cm dbh and retained within 10 m of the stream channel form most potential LWD currently available for these S4 fish streams 2–3 years after the cutblocks were harvested. The future supply of potential LWD for the surveyed streams includes these larger stems together with those that are currently < 15 cm dbh after they grow to the minimum size required for functional LWD.

Estimates of retention of large-diameter trees (≥ 15 cm dbh; either conifers or deciduous trees) within 10 m of the channel margin were made by extrapolating tree counts from two 50-m^2 plots on the harvested side of the stream to the riparian area contained along 100 m of stream (Figure 8a). This graph is meaningful for comparisons between riparian silviculture treatments only if it can be assumed that natural stand densities were, on average, similar for all treatment types. Even if comparisons are not valid by that criterion, the numbers may provide a picture of the amounts of large-tree retention around S4 fish streams.

The mean numbers of large trees in the boundary reserve (56 ± 36), fixed-width reserve (45 ± 17), variable-reserve (48 ± 22), and partial-retention (30 ± 22) categories are not significantly different (all $p > 0.05$; all means provided with ± 95% CI).

Despite the small number of streams within some of these riparian treatment categories, tree numbers are significantly higher in plots from the boundary reserve, fixed-width reserve, and variable-width reserve categories compared with clearcuts (all $p < 0.05$).

When average tree retention within 10 m of the stream channel is separated into different size classes of trees (Figure 8b), the trends among riparian treatments are similar to those shown in Figure 8a. For the largest size class of trees (those > 30 cm dbh), boundary reserves retained the most trees (35) per 100 m of channel, followed by fixed-width reserves (22), variable-retention reserves (14), partial-retention treatments (10), and clearcuts (6). Retention of trees in the 15- to 30-cm dbh class was similar among boundary,

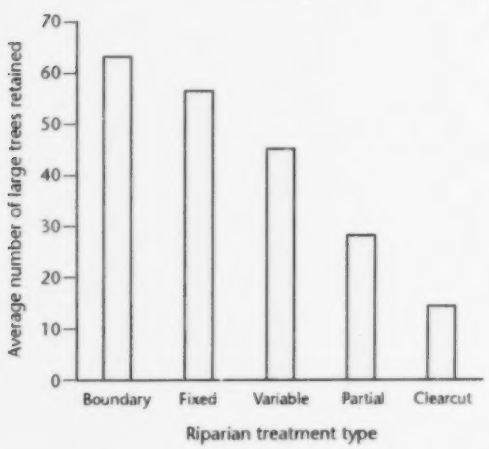

FIGURE 8a *Average number of large trees (≥ 15 cm dbh) retained within 10 m of the channel for the five riparian treatment categories.*

fixed-width, and variable reserves, and ranged from 28 to 35 trees per 100 m of channel (Figure 8b). Partial-retention and clearcut treatments, respectively, retained 18 and eight trees in the 15- to 30-cm dbh class per 100 m of channel.

Clearcut riparian treatments retained, on average, 14 large trees within 10 m of the stream per 100 m of channel (Figure 8a). Figure 8c shows the distribution of this retention across the 16 clearcut sites. Eleven clearcut treatments (69% of the total) retained 10 or more large trees per 100 m of channel. Twenty or more large trees were retained in six of those 11 cases (Figure 8c). In addition, two of the 11 cases retained 40 and 60 trees, respectively (mainly aspen).

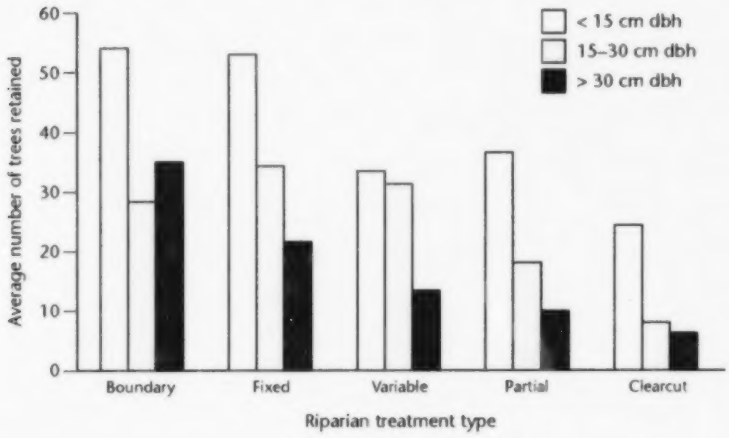

FIGURE 8b *Average number of trees retained by diameter class within 10 m of the channel for the five riparian treatment categories.*

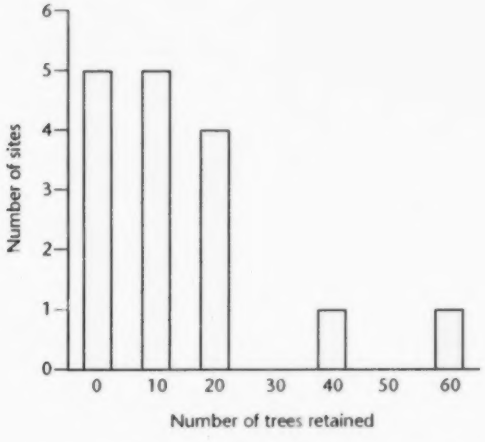

FIGURE 8c *Retention of large trees (≥ 15 cm dbh) within 10 m of the channel per 100 m of reach in the 16 clearcut riparian treatments.*

In five of the 16 clearcut riparian treatments (31%), no large trees were retained within 10 m of the stream on either side of the channel (Figure 8c). The future supply of riparian LWD for these channels depends fully upon the growth of any small stems retained, and thus may not have an LWD supply for several decades. On average, about 25 small trees < 15 cm dbh were retained per 100 m of channel.

The lack of a present source of new LWD in five of the riparian clearcut treatments in question might be raised as a concern. However, this potential concern must be tempered by the observations that (1) the frequency of these cases is very low, (2) existing in-stream LWD remains intact, (3) the retention of small stems provides some future source of in-stream wood, and (4) the channels in question have a low capacity to transport sediment and debris.

Scientific studies have neither identified the minimum LWD requirements of these small, relatively low-energy streams, nor the minimum levels of riparian retention needed to provide this LWD. In addition, the longevity of LWD currently existing within these streams is very difficult to estimate. For these reasons, it is difficult to interpret the observed levels of retention around S4 fish streams in terms of long-term LWD requirements.

Stream channel impact was assessed on 69 of the 72 valid S4 fish streams. This impact was determined by measuring the total length of stream channel with a moderate or high level of channel disturbance. The Methods section explains how the length of disturbed channel was converted into an overall rating of nil, low, moderate, or high stream channel impact. The stream channel disturbance reported is only that recorded 2–3 years post-harvest and does not address long-term stream channel conditions.

The complete list of all streams with an overall low, moderate, or high channel impact is listed in Table 2. The table lists the treatment type, the Overall Channel Assessment Rating (OCAR), the percentage of the channel affected to a low, moderate, or high degree, and the causes of the impact.

TABLE 2 *Low, moderate, and high channel impact ratings*

Treatment	Cause 1	Cause 2	Percent of channel sites with low rating	Percent of channel sites with moderate or high rating	OCAR
Boundary	Windthrow		0	10	M
Boundary	Road		2	1.5	L
Clearcut	Skid trail	Windthrow	0	8	M
Clearcut	Windthrow		3	0	L
Clearcut	Livestock		5	0	L
Clearcut	Slash		10	0	L
Clearcut	Livestock		4	3	L
Clearcut	Windthrow		3	12	M
Fixed	Windthrow		15	0	L
Fixed	Beaver		2	0	L
Fixed	Livestock	Windthrow	6	3	L
Fixed	Livestock		5	95	H
Partial	Slash		10	0	L
Partial	Windthrow		6	0	L
Partial	Windthrow		0	14	M
Partial	Livestock		0	100	H
Partial	Windthrow		2	2	L
Variable	Slash		14	0	L
Variable	Livestock		25	75	H
Variable	Windthrow		0	4	
Variable	Windthrow	Livestock	5	4	L
Variable	Debris		0	27	M
Variable	Debris	Livestock	8	2	L
Variable	Livestock		0	100	M
Variable	Fireguard	Livestock	36	8	M

Forty-four streams of the 69 surveyed (64%) showed no evidence of stream channel disturbance (Photo 8). Twenty-five streams (36% of the stream population) had either a low, moderate, or high level of stream impact from all causes.

Ten streams had a moderate or high channel impact from all causes. Six of these 10 streams experienced moderate impacts and four were rated with high impacts. Figure 9a shows the frequency of moderate or high stream channel impact ratings for each riparian treatment type. Partial-retention treatments are most frequently associated with stream impacts, because 33% of these blocks (two of six) had moderate or high impacts. Variable-width reserves were a close second, with 28% of their blocks having affected streams. The two fixed-reserve treatments had low impact frequencies (4–7%), while clearcut treatments were intermediate, with 13% of clearcut blocks associated with affected streams.

PHOTO 8 *Most of the streams investigated, especially streams with reserves, showed no channel disturbance as a result of forest harvesting or windthrow.*

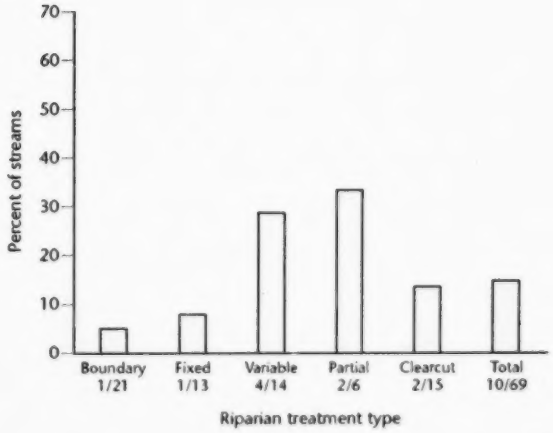

FIGURE 9a *Frequency of moderate or high stream channel impacts (for all causes) by riparian treatment type. (Number of affected streams with sample size shown for each treatment type.)*

Figure 9b is a similar analysis but only for impacts related to harvesting and post-harvest windthrow. Examples of forest harvest impact are skid trails through a stream, slash and debris in the stream causing channel aggradation, and direct machinery damage to streambanks (Photo 9). The frequency

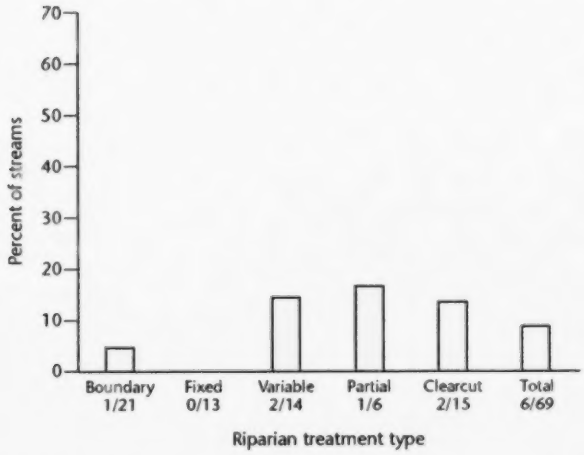

FIGURE 9b *Frequency of moderate or high stream channel impacts (for harvesting-related causes) by riparian treatment type. (Number of affected streams and sample size are given for each riparian treatment type.)*

PHOTO 9 *Six streams had moderate levels of channel disturbance associated with harvesting practices and post-harvest windthrow.*

of cases is very low: only six streams (8% of the total) had harvest and windthrow-related disturbance at the moderate level. No channel disturbances that were caused by harvesting or post-harvest windthrow were rated high. Patterns in Figure 9b are similar to those in Figure 9a, and show that riparian stands that have been entered (variable, partial, and clearcut) have greater impacts than reserves (fixed-width and boundary). The differences among clearcut, partial, and variable are not significant at the 95% confidence level.

Because of the low frequency of disturbances due to harvest and post-harvest windthrow, a further analysis (Figure 9c) included streams with low, as well as moderate, impacts from harvesting (four streams) and post-harvest windthrow (11 streams) for a total of 15 affected streams (21% of the population). Partial-retention harvesting had a statistically higher level of disturbance compared with other treatment types because 67% of the surveyed partial-retention streams had at least a low level of disturbance. Variable-width reserves and clearcutting had statistically similar frequencies —about 30% of sampled streams—while streams within fixed-width and boundary reserves were affected the least.

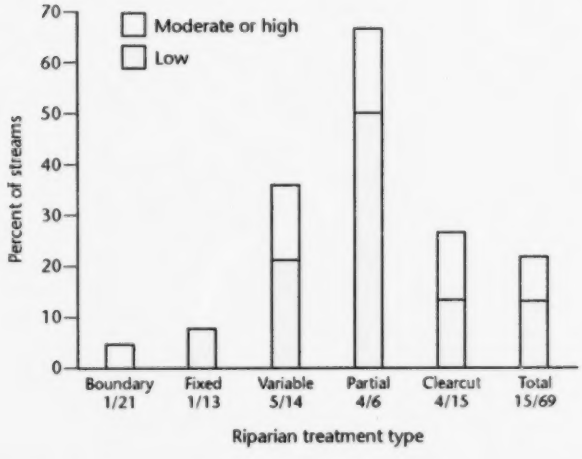

FIGURE 9C *Frequency of low, and moderate or high, stream channel impacts (for harvesting-related causes) by treatment type. (Number of affected streams and sample size are given for each riparian treatment type.)*

Moderate or high levels of channel disturbance were recorded for 10 streams of the 69 assessed for channel impact. Four of the 10 cases were rated high. There are three primary causes of channel disturbance: livestock, post-harvest windthrow, and harvesting (Figure 10a). Livestock was responsible for 40% of the cases, affecting four streams (Photo 10). Post-harvest windthrow was responsible for 30% of the cases, affecting three streams (Photo 11). Causes directly related to harvesting accounted for 20% of the moderate impacts (two streams), and there was one case of fireguard-related impact.

Where livestock had access to a stream, the stream channel was often affected to a high level. In three cases, impacts of 75–100% of the surveyed stream length were observed (Photo 12). The only occurrences of high channel disturbance in this survey were associated with livestock. Cattle access to streams might be improved as a result of forest harvesting. However, it was

not possible to generalize from the results of the present study that cattle access was clearly associated with harvesting by any of the riparian silviculture treatments because (1) the number of affected sites was low, and (2) cattle also used trails and fords that existed prior to harvesting to gain access to streams. At one heavily affected site, trails extended along both banks of the stream from the point of access at a well-established cattle ford (Photo 10).

A further analysis was made of the causes of the low as well as the moderate and high channel impacts (Figure 10b). There were 25 stream channels with a low, moderate, or high level of channel disturbance. Windthrow, livestock, and harvesting were all statistically equivalent causes of channel disturbance. Each of these three agents accounted for about 30% of all disturbances.

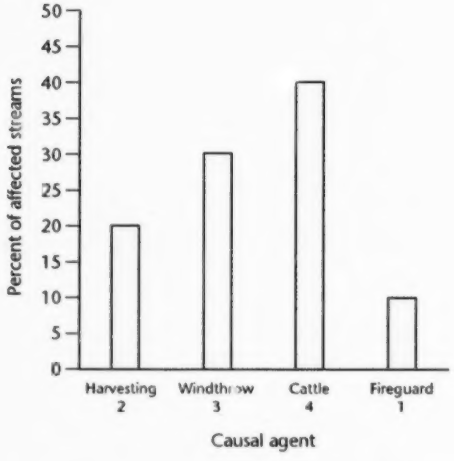

FIGURE 10a *Frequency of moderate or high channel impact by causal agent. (Cases of occurrence are given for each causal agent.)*

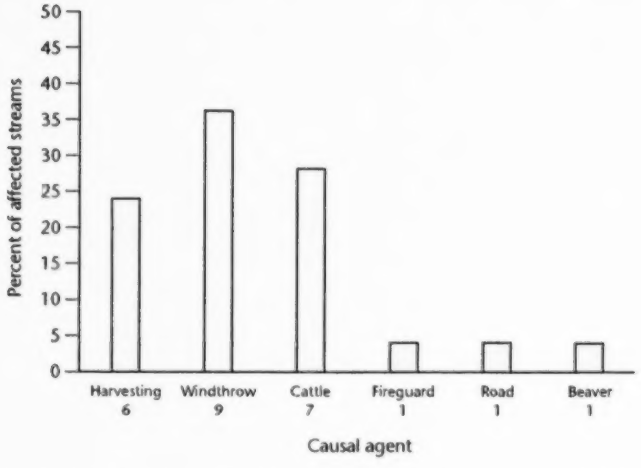

FIGURE 10b *Frequency of low, moderate, or high channel impact by causal agent. (Cases of occurrence are provided for each causal agent.)*

PHOTO 10 *Cattle using stream fords resulted in localized high stream channel impact.*

PHOTO 11 *Windthrown streambank tree exposing the root system to the channel and serving as a source of sediment to the stream.*

PHOTO 12 *On some streams, 50–100 % of the stream length was moderately to highly affected by livestock churning of the banks and bed.*

Assessment procedures and the rating system for windthrow hazard are discussed in the Methods section. Figure 11 depicts the frequencies of both moderate and high levels of windthrow for each riparian treatment type. Windthrow can occur in clearcut treatments because the usual practice is to retain non-merchantable trees within the inner 5 m of the RMA.

Overall, high windthrow occurred in 24% of the RMAs of the cutblocks and moderate windthrow occurred in an additional 22% of the RMAs. In total, 46% of the cutblocks had a moderate or high windthrow. However, there were no statistically significant differences among riparian treatments ($p > 0.05$). Partial-retention treatments may have a greater likelihood for experiencing high levels of windthrow. The occurrence of harvest-associated windthrow is widely recognized; however, it is difficult in the present study

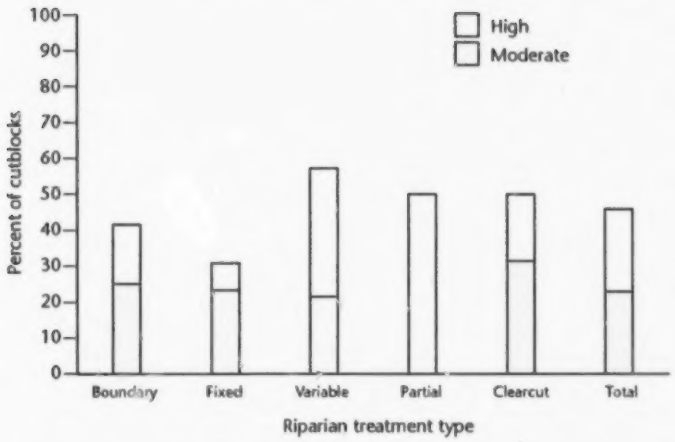

FIGURE 11 *Frequency of cutblocks with post-harvest windthrown trees, by riparian treatment type.*

to associate levels of windthrow with specific riparian silviculture treatments. First, pre-harvest levels of windthrow are unknown for the sites surveyed. Second, in order to isolate the effects on windthrow frequency caused by each riparian silviculture treatment, the complicating factors of forest stand type, topography, terrain stability, soil characteristics, and hydrology must be assessed and accounted for.

This analysis assumed that windthrow hazard was similar for all sites. We conclude that there is a risk of at least moderate levels of windthrow in most riparian areas, irrespective of the type of riparian silviculture treatment implemented.

When windthrow does occur, there is a good chance that trees will fall across the stream channel. However, this result is not necessarily considered an impact because it is usually desirable that trees eventually enter the channel.

Overall, more than three streamside trees (per 100 m of channel) were blown over and fell across or entered the stream channel in 32% of the cutblocks (Photo 13). Because the overall frequency of moderate or high windthrow is 46% (Figure 11), the potential frequency of three or more trees falling across a stream channel, given that windthrow has occurred, is more than 70%.

While the frequency of moderate or high windthrow is the same for all treatment types (Figure 11), there is a difference between treatments in the likelihood that the trees will reach the stream (Figure 12). Partial-retention and variable-width reserve treatments have a substantially greater likelihood of having three or more windthrown trees reaching the stream channel compared to other treatment types.

Post-harvest windthrow concerns and the consequent impact that windthrow may have on stream channels is often cited as a reason for not retaining trees around streams. Eleven of the 69 surveyed streams were affected by post-harvest windthrow, where 11% experienced a low channel impact and another 5% experienced a moderate impact (Photo 14). No streams had a high channel impact due to windthrow. It is important to

PHOTO 13 *Windthrow is common in all treatment types. Seventy percent of cutblocks with windthrow in the RMA had trees that fell across the stream channel.*

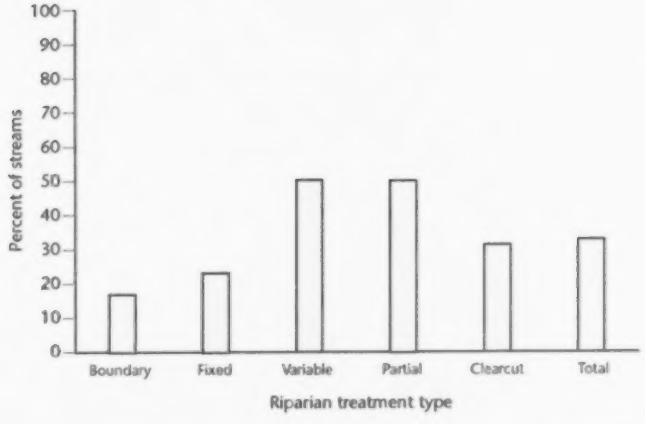

FIGURE 12 *Frequency of streams with three or more windthrown trees in the stream channel, by riparian treatment type.*

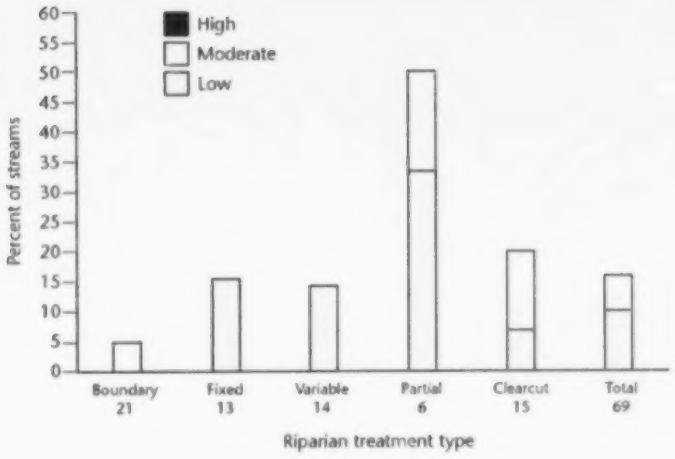

FIGURE 13 *Frequency of streams with low, moderate, or high channel impacts due to post-harvest windthrow, by treatment type and by all treatments combined. (Number of assessed streams is given for each riparian treatment type.)*

PHOTO 14 *While windthrow is common, stream channel disturbance associated with windthrow is relatively rare. Only 5% of the streams had a moderate level of channel disturbance due to windthrow. This occurred only where root stocks tore away streambanks and delivered sediment directly to the channel.*

recognize that this survey was conducted 2–3 years after harvesting, so the number of windthrown trees may increase over time.

We conclude that the overall short-term channel disturbance due to windthrow (for all treatments combined) 2–3 years after harvest is not significant.

Streambank trees, defined as trees that have at least some portion of their root systems growing within the stream channel bank, are important aquatic habitat elements (Photo 15). They provide streambank stability, high-water refuge, cover, and structure. The harvest of streambank trees is discouraged in the *Riparian Management Area Guidebook*, and its occurrence may be considered a potential impact to fish habitat.

PHOTO 15 *Loss of streambank trees was documented, but little disturbance to the streambed and banks was observed. Streambank trees had at least part of their root systems within the stream channel bank.*

Figure 14 plots the average number of streambank trees harvested by riparian treatment type. Clearcuts had an average of five streambank trees cut per 100 m of stream channel. A high value was recorded in only two clearcut riparian treatments, where 14 trees and 22 trees were harvested along two streams within the same cutblock (see Photos 16 and 6c). In other treatment types, the frequency of streamside trees harvested was less than two trees per 100 m (Photos 15 and 17), and in no individual case did the number of harvested streambank trees exceed four trees per 100 m.

When streambank trees were harvested, very little ground, streambank, or channel disturbance was observed as a result of felling and removal (yarding). Harvesting was apparently performed with minimum physical damage

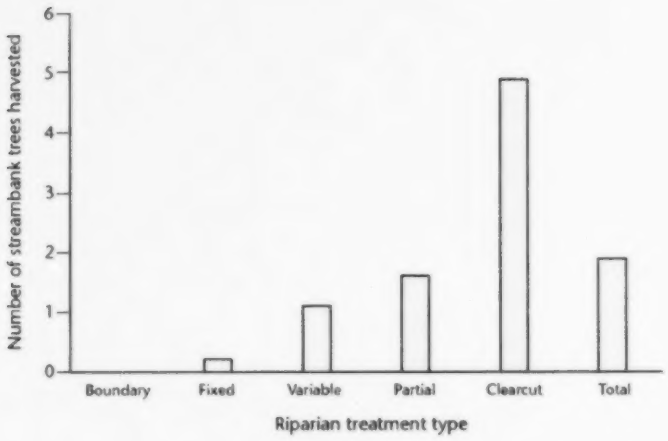

FIGURE 14 *Average number of harvested streambank trees, by riparian treatment type.*

PHOTO 16 *Frequent streambank tree harvest occurred at two sites. An example is shown in this clearcut block.*

PHOTO 17 *In most sites where streambank trees were removed, only two trees were taken, leaving most streambank trees in place along the 100-m study reaches.*

and little noticeable impact. For example, impacts such as channel evulsion, compacted banks or bed, or collapsed banks were not observed.

In terms of harvest-related impacts, only the two clearcut riparian treatments with 14 and 22 streamside trees removed were considered to be potential impacts.

Riparian shade loss was used as a surrogate variable to indicate potential stream temperature concerns for fish, habitat cover, and changes in the availability of organic (leaf) litter for the stream ecosystem. Stream temperatures were not monitored, given the season and short duration of the study. Additionally, the influence of elevation was not determined, and the presence of fish was not confirmed, so it is unknown whether actual temperature concerns exist in any of these streams. Single readings taken with alcohol thermometers at a number of locations and elevations revealed that October water temperatures were ≤ 6°C (readings usually taken between 09:30 and 17:30).

Twenty-six streams were estimated to have moderate or high loss of canopy shade (Figure 15a). High canopy shade loss was recorded in 11 of these 26 cases. Additionally, 19 of the 26 streams were estimated to have moderate or high loss of total shade (Figure 15a). Overall, moderate or high levels of loss of total shade occurred along 30% of all surveyed streams, and similar canopy shade loss occurred along 47% of the streams. High loss of total shade was restricted to five cutblocks (7% of the total), all clearcuts.

The frequency of streams that experienced moderate or high levels of shade loss are plotted for each riparian treatment type (Figure 15a). Bound-

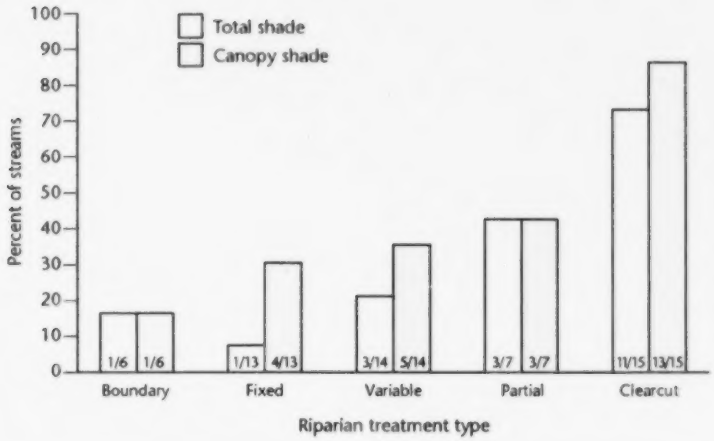

FIGURE 15a *Frequency of streams in various riparian treatment types with moderate or high shade loss. (Cases of occurrence and sample size are given for each riparian treatment type.)*

ary reserves had moderate or high shade loss (usually the result of windthrow) in fewer than 17% of the cases for both canopy and total shade.

Variable-width reserves have moderate or high canopy shade loss on 36% of the streams and moderate or high total shade loss on 21% of the streams. Partial-retention treatments have moderate or high shade loss in 42% of the cases. For the variable-width and partial-retention treatments, high loss of canopy shade was recorded at only one and two sites, respectively.

Only 8% of streams with fixed-width reserves (one of 13 streams) experienced shade loss in the moderate-or-high category. In addition, four streams with fixed-width reserves (31%) had moderate levels of canopy shade loss.

Clearcut practices have frequent occurrences of shade loss, and was the only treatment category within which high shade loss was recorded. Shade loss was assessed in 15 of the 16 clearcuts. Streams with clearcut streamside treatments had moderate or high loss of canopy and total shade in 87 and 73% of the cases, respectively (Figure 15a). Within the moderate-or-high category, moderate canopy shade loss and total shade loss occurred, respectively, in 40 and 34% of riparian clearcut treatments (Photo 18).

High loss of canopy shade occurred in 53% of clearcut riparian treatments (Figure 15b), but in nearly half of those sites the loss of canopy shade was partly compensated for by the shade provided by understory vegetation along the streambanks. Understory vegetation occurring near the channel level was primarily responsible for reducing the amount of total shade loss around streams experiencing reductions in canopy shade.

The graph of the frequency of streams with a high shade loss (Figure 15b) indicates that high loss of total shade was restricted to five clearcut treatments (33% of the 15 clearcuts). These sites were the same five where no large trees were retained within 10 m of the channel (Figure 8c; Photo 6c), and included the two clearcut sites with 14 and 22 streambank trees removed, respectively, per 100 m of channel. These sites, amounting to 7% of the population of surveyed S4 fish streams, are the ones of greatest concern for potential impacts to fish habitats related to temperature and reductions in the amounts of organic litter for the stream ecosystem.

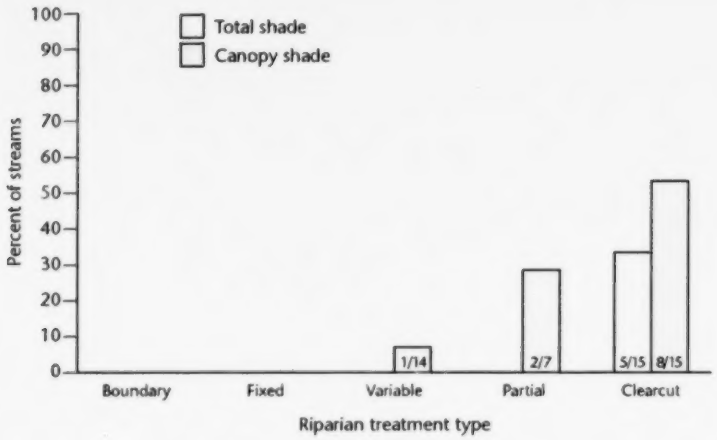

FIGURE 15b *Frequency of streams in various riparian treatment types with high shade loss. (Number of cases and sample size are given for each riparian treatment type with affected streams.)*

PHOTO 18 *Moderate to high shade loss occurred in some clearcut and partial-retention cutblocks.*

Similar to the previously noted cautions on whether actual temperature concerns exist at the surveyed sites, the biological significance of the reductions in organic litter input for fish is unclear. Shifts in the abundance of aquatic invertebrates depending upon organic detritus can be expected, but the amount of this change compensated for by post-harvest increases in the abundance of invertebrates supported by elevated levels of primary production is unknown.

3.3 Summary of Findings

The condition of designated S4 fish streams in the central interior of British Columbia was investigated in response to forest harvest practices implemented in the Riparian Management Zone under the Forest Practices Code. The survey documented the extent of forest harvesting potentially affecting small fish-bearing streams (S4s), the prevalent riparian silviculture treatments implemented and degrees of tree retention, the evidence for stream channel disturbance 2–3 years after forest harvesting, the degree of shade loss over the stream, and the extent of windthrow and windthrow-related impacts to the stream.

3.3.1 Extent of forest harvest potentially affecting S4 fish streams

- Forest harvesting occurred adjacent to a relatively small number of S4 fish streams. In the six forest districts, 2989 cutblocks harvested in 1996–1998, covering an area of 47 800 ha, affected only 72 valid streams classified as S4 fish streams. Only 2.4% of the cutblocks contained or were immediately adjacent to one or more designated S4 fish streams.
- Fish inventory was rarely used to identify these streams as fish-bearing (S4); instead, a default classification based on channel gradient was used in 87% of the cases. Some of the sites identified as S4 fish streams (16% of the total) did not meet the FPC definition of a stream.

3.3.2 Types of riparian harvest treatments

- A broad range of riparian harvest treatments was implemented. Some type of reserve (boundary, fixed-width, or variable-width) was used in 68% of the cutblocks; partial-retention methods were used 10% of the time, and clearcuts 22%.
- The level of forest retention varied with treatment type. In the innermost 10 m of the RMA, tree retention ranged from an average of 17% for clearcuts, to 63% for variable-width reserves, 62% for partial-retention treatments, and to nearly 100% for fixed-width and boundary reserves.
- The overall average tree retention (all treatment types combined) in the 30-m-wide RMA was 49%. This included retention around boundary treatments, where the stream may have been beyond the cutblock boundary. Excluding boundary reserves, the average tree retention across the RMA is 43%. These percentages are not direct measures of basal area retention; however, overall forest retention around S4 fish streams appears to be considerably higher than the 25% basal area retention recommended (for balancing timber supply impact with retention) in the *Riparian Management Area Guidebook.*

3.3.3 Stream channel impacts 2–3 years after forest harvesting

- Of the 69 streams assessed for stream channel disturbance, 10 streams (15%) had a moderate or high level of stream channel impact. Of these 10 streams, four had high levels of channel disturbance, all due to livestock. Fifteen streams (21%) had a low level of stream channel impact from all causes.
- Six streams (8%) had a moderate (no highs observed) stream channel impact associated with forest harvesting (two streams) or post-harvest windthrow (four streams).
- Considering all levels of stream channel impact, the main causes of channel disturbance were livestock, post-harvest windthrow, and forest harvesting.
- Channel disturbance due to forest harvesting and post-harvest windthrow was more commonly associated with partial-retention harvesting. Full-width reserves were associated with the least likelihood of channel disturbance, and clearcutting and variable-width reserves were intermediate.

3.3.4 Harvested streambank trees

- All riparian treatment types except boundary reserves had some streambank trees harvested. Harvest frequency was low, averaging fewer than two trees per 100 m of streambank in all treatments except clearcuts. Clearcuts had the highest levels of harvested streambank trees (averaging five trees per 100 m), but only two streams had levels that are considered a potential future problem.
- For all but two streams, the risk of future problems for streambank and channel bed integrity is considered to be minimal because: (1) harvesting was performed with very little apparent physical disturbance to the ground, streambed, or streambanks; (2) few streambank trees were removed relative to the numbers retained; (3) S4 fish streams have a limited capacity to erode and transport mineral aluvium from the streambed and banks due to low hydraulic power; and (4) the remaining understory vegetation contributes to streambank and channel integrity.

3.3.5 Shade loss due to loss of streamside understory and canopy shading

- High loss of total shade occurred along only five streams (7%), all within clearcuts. These sites are the same ones where no retention of large trees occurred around the stream and are of greatest concern for potential impacts to fish habitats related to temperature and reductions in the amounts of organic litter for the stream ecosystem. High total shade loss did not occur in any other treatment type.
- An additional 23% of the streams, all clearcut or partial-retention treatments, experienced moderate levels of total shade loss.
- Clearcut harvesting treatments have high losses of total shade in 33% of the cases. High total shade loss did not occur in any other treatment type.
- Shade loss and the potential implications for water temperature and organic litter input for the streams were moderated in 11 clearcut treatments (69%) by retention of 10 or more large trees (> 15 cm dbh) per 100 m of channel. In six of these 11 cases, 20 or more (up to 60) large trees were retained.

3.3.6 Windthrow within Riparian Management Areas

- A moderate or high level of windthrow occurred in 46% of the Riparian Management Areas of the surveyed cutblocks. High levels of windthrow occurred in 24% of the streams and moderate windthrow occurred in an additional 22% of the study sites.
- Moderate windthrow is common in all treatment types, but high windthrow is most commonly associated with partial-cut treatments.
- When moderate or high windthrow occurs in cutblocks, the results of this study suggest that there is a 70% probability that trees will fall across the stream.
- Windthrow does not usually result in a moderate or high stream impact in spite of its common occurrence. While 46% of the cutblocks experienced a moderate or high level of streamside windthrow, only 16% of the streams had any level of channel disturbance as a result of windthrow and only 5% of the streams experienced a moderate impact. There were no high impacts associated with windthrow.

3.3.7 Livestock impact on small streams

- Livestock had an impact on 6% of the streams surveyed and were one of the primary causes of stream channel disturbance (40% of the cases). In some cases, livestock impact was up to 100% of the stream length. The impacts were mainly from churning of the streambed and streambanks by hooves, such that the channel became excessively wide, laden with fine sediment, and sometimes discontinuous.

3.3.8 Non–fish-bearing S6 streams directly tributary to the S4 fish streams

- Only five S6 streams were encountered that were direct tributaries to one of the 72 designated S4s that were valid Code streams. This study was not able to address issues of S6 riparian management and its effects upon fish habitats because of the very small number of direct-tributary S6 streams and the lack of forest harvesting around them. No channel disturbances were observed in any of these streams.
- The actual fish-bearing status of most of the designated S4 fish streams is unknown because most were classified on the basis of channel gradient alone, and, in a number of cases, their status is questionable for one or more of the following reasons: occurrence in high-elevation sites remote from the nearest known fish-bearing waters; location upslope of significant topographic breaks; seasonal flows; and small size (< 0.5 m wide) with limited aquatic habitat.
- The small number of S6 streams might partly be explained by the possibility that some of the low-order, headwater channels designated and managed as S4 fish streams were class S6 non–fish-bearing tributaries.

4.1 Cautions on Extrapolating the Results

This survey was restricted to six forest districts in the central interior plateau. Results and conclusions should not be extrapolated to other physiographic or biogeoclimatic zones where stream density, stream gradient and power, and riparian vegetation characteristics are different.

Similarly, the five prevalent riparian silviculture treatments implemented for the designated S4 fish streams that were identified from the survey of SPs, and confirmed in the field, apply only to the area studied.

The conclusions made in this study are based on the entire population of 72 designated S4 fish streams associated with harvest treatments outside of community watersheds. However, these conclusions are constrained by the small number of S4 fish streams encountered and the yet smaller number of affected streams. These low numbers were then divided among five riparian treatment types. Due to the small number of streams available for this study, most of the differences between the treatment types were not statistically significant at the 95% confidence level.

The results on stream channel disturbances and incidence of windthrow were measured 2–3 years post-harvest. Therefore, this report is primarily a summary of the short-term environmental effects of the application of FPC riparian standards and guidelines. For example, more windthrow may occur before second growth becomes established to buffer the riparian stand. The long-term effects of riparian practices on the biological and physical attributes of small streams are not well known, and are outside of the scope of this investigation. Therefore, there are strict limitations to any extrapolation of existing channel and riparian conditions for forecasts on the likelihood of long-term disturbances to stream channels and their fish habitats.

For example, the potential long-term impacts on channel stability were not assessed. Such assessments are complicated by the lack of scientific information on the minimum levels of riparian tree retention needed to satisfy long-term LWD requirements for small stream channels. To meet its objectives for S4 fish streams, the *Riparian Management Area Guidebook* recommends levels of tree retention at the site level and across areas covered by forest development plans. Our opinion is that, across the landscape, sufficient trees have been left along most of these streams that long-term LWD supply should be achieved.

4.2 Estimation of Effects on Fish Habitats

Quantitative pre-harvest information was not available on fish populations and other biological attributes or processes (aquatic invertebrates, leaf litter input, etc.) for the surveyed streams. The effects of existing Forest Practices Code riparian practices on fish habitats were therefore assessed indirectly by inference from observed alterations to stream channels and riparian cover that could be attributed directly to forest harvesting or to post-harvest windthrow. The physical state of stream channels and banks, the loss of streamside trees, and the loss of riparian shade were used as surrogates for the physical and biological integrity of fish habitats. For example, riparian shade loss was used as a surrogate for potential changes to seasonal water temperatures and organic (leaf) litter input for the stream ecosystem.

Fish presence or absence was not confirmed: for the purposes of this study, fish presence was presumed from the stream's FPC classification. Because most of the 72 designated S4 fish streams were classified on the basis of channel gradient alone, some of these low-order headwaters may actually

have been small non–fish-bearing tributaries, thus explaining the apparent lack of classified S6 tributaries throughout the area examined.

4.3 Comparisons of Riparian Treatments

The comparative efficacy of the different riparian treatments in protecting streams must be considered preliminary because of the small number of streams adversely affected. For impacts directly attributable to forest harvesting, only two streams had moderate levels of channel disturbance (no high impacts seen), only two had levels of streambank tree harvest considered sufficient to be potential impacts, and five experienced high levels of shade loss due to the removal of virtually all trees adjacent to the channel. Moreover, some of these impacts were observed within these same sites, a small subset of the total population.

Reserves (boundary reserves or fixed-width reserves) appear to provide the best combination of stream channel stability, shade, and windthrow resistance. Levels of tree retention approached 100% within 10 m of the stream channel, and either met or substantially exceeded site-level recommendations for RMA retention within the *Riparian Management Area Guidebook*. The guidebook's objectives of minimizing or preventing impacts of forest and range uses on stream channel dynamics, aquatic ecosystems, and water quality appeared to be achieved for all streams within these two riparian treatments.

Variable-width reserves and partial-retention treatments respectively retained on average 63 and 62% of the forest in the innermost 10 m of the RMA. Most reaches surveyed within these two riparian treatments (72% for variable reserves and 67% for partial retention) were observed with no impacts or low levels of channel alteration. Partial-retention treatments (10% of the total) had the highest proportion of stream channel stability concerns and windthrow incidence, and a moderate risk of shade loss. However, these observations must be tempered by the small number of streams affected. In addition, observations made in this survey indicate that windthrow is infrequently associated with adverse effects on small stream channels. Therefore, at least for the short term, most streams within these intermediate-level treatments appear to be meeting *Riparian Management Area Guidebook* environmental objectives for streams, while at the same time meeting the guidebook's related objective of allowing for forest and range use that is consistent with the environmental objectives.

Clearcutting, as carried out in these districts, appears to provide adequate channel stability and windthrow resistance 2–3 years after harvest, but has a higher likelihood of shade loss and loss of streambank trees. However, clearcut riparian treatments still retained deciduous and non-merchantable trees amounting on average to 17% of all trees within 10 m of the channel and 22% within 5 m of the channel. This retention, which represents an average of 14 large (> 15 cm dbh) and 25 small (< 15 cm dbh) streamside trees retained per 100 m of channel, provides more shade, canopy leaf litter, and future LWD supply than is often expected from clearcut practices, which are generally assumed to remove all trees. (Trees currently ≥ 15 cm dbh are sufficiently large to function as LWD in these narrow, shallow channels.)

There was a wide variation in riparian retention across the 16 clearcut treatments; however, 11 of them (69% of the total) retained 10 or more large trees per 100 m of channel. Twenty or more (up to a maximum of 60) large trees (mainly aspen) were retained in six of those 11 cases. This level of retention, found in more than two-thirds of the clearcut riparian treatments, is consistent with the intent of the *Riparian Management Area Guidebook*

objectives. However, it is difficult to conclude unequivocally whether these objectives are being achieved by these levels of retention, because the thresholds for riparian tree retention required for LWD supply, organic litter input, and temperature modulation have not been identified through scientific study.

On the other hand, no large trees were retained near the stream in five of the 16 clearcut riparian treatments (31%). The current lack of a source of future LWD in these five clearcut treatments is a potential concern. Additionally, the two sites with channel stability concerns associated with streamside tree harvest are included within this subset of five streams. Concerns also exist from the viewpoint of potential stream temperature impacts as a result of high loss of total shade. None of the surveyed sites has been identified as a temperature-sensitive stream or a direct tributary to a temperature-sensitive stream. However, the potential for temperature-related impacts may exist, given the proper conditions of elevation, aspect, and other contributing factors. In the 11 other clearcut sites, loss of canopy shade was moderate or low, and partly compensated for by the growth of streamside understory vegetation 2–3 years after harvesting.

Harvest-related impacts and concerns such as future LWD supply, shade, leaf-litter input, and channel stability pertain to a relatively small number of sites. These concerns should not be downplayed, but should also be considered within the context of the large majority of the 72 designated S4 fish streams where riparian retention was at levels consistent with the intent of *Riparian Management Area Guidebook* objectives, and which likely achieved them at least in the short term.

The only occurrences of high channel disturbance in this survey were associated with livestock. Trampling of the streambed and banks sometimes affected the entire length of the surveyed reaches. However, interactions between forest harvesting and the incidence and degree of cattle-caused impacts to the streams were difficult to quantify. It was not possible to clearly associate any of the five categories of riparian silviculture treatments with cattle-related impacts because the number of affected sites was low, and cattle were also able to gain access to streams by trails and fords that existed prior to harvesting.

4.4 Wildlife Values

The SP review and field survey revealed that the incorporation of wildlife tree patches into the Riparian Management Areas of designated S4 fish streams is a common practice. However, current knowledge of the relationships between small-stream riparian areas and wildlife is incomplete and requires substantial research to answer several basic questions. Evaluations of the effectiveness of riparian retention for maintaining local terrestrial wildlife values and biological diversity were therefore outside the scope of this study.

5 CONCLUSIONS

This survey of the condition of small, designated fish-bearing streams managed under the Forest Practices Code in the central interior of British Columbia documented an overall low level of alteration to potential fish habitats 2–3 years after harvesting. A wide range of riparian silviculture treatments had been implemented. Riparian management practices around most of these small, designated fish-bearing streams met the objectives of the *Riparian Management Area Guidebook*, in particular by protecting channel and bank stability, providing stream shade, and providing a source of large woody debris (LWD).

The overall frequency of impacts on the designated S4 fish streams resulting from forest harvesting or post-harvest windthrow was low: 8% of the streams had a moderate level of stream channel impact, 7% had high shade loss, and 3% had high streambank tree loss. Ten streams (15% of the total population) had a moderate or high level of some potential impact on fish habitat. Within this group, four streams were observed with high levels of impact. (Note that this stream total is less than the sum of impacts because one stream included two impact types.) Streams with reserves sustained less impact than those without reserves, but the levels of impact were small for all treatment types.

Across the landscape of the central interior, S4 fish streams are not a common feature either in or adjacent to cutblocks. In the 43 000 ha of cutblocks, there was only 12.2 km of designated S4 fish stream affected by forest harvesting, or 283 m of S4 fish stream per 1000 ha logged. The question of the cumulative watershed effects of riparian management along S4 fish streams and their direct tributaries cannot be fully addressed within the scope of this study. However, the cumulative impact of forest harvesting on these small streams alone is considered to be low, given the low numbers of these streams distributed over 2989 cutblocks across six forest districts, the low frequency of moderate or high impacts observed, and the limited capacity for these small streams to transmit these impacts downstream.

The overall tree retention around S4 fish streams has been conservative, averaging 43% of the RMA retained (49% if boundary reserves are included). This level of retention well exceeds the site-level recommendations in the *Riparian Management Area Guidebook* for riparian retention around interior S4 fish streams. The *Riparian Management Area Guidebook* also recommends, in terms of tree basal area, a 25% maximum overall riparian retention across all S4 fish streams within a forest development plan (as a target for limiting timber supply impacts). Riparian retention is presently estimated from tree count data and not from basal area calculations and is thus not directly comparable with the *Riparian Management Area Guidebook* recommendation. However, given the observations that 68% of the study streams were provided with some form of riparian reserve, and that more than 30% of the RMAs had reserves > 10 m to 50 m wide, it appears that the guidebook recommendations for retention around S4 fish streams were exceeded across the six forest districts.

APPENDIX 1 Best Management Practices for management zones adjacent to S4 streams in interior forest districts (from the *Riparian Management Area Guidebook*, Forest Practices Code of British Columbia, December 1995)

The primary objective of the management zone of S4 streams in the interior is to provide for the protection and management of fisheries, important wildlife habitats, and water quality associated with these streams. These streams provide important furbearer as well as fisheries habitat and significantly influence downstream fisheries values. Timber harvesting and other activities should be consistent with the requirement to maintain stream channel processes, stream temperatures, wildlife trees, and habitat for furbearers and other wildlife.

Best Management Practice

- Retain all trees within 10 m of the streambank.
- Retain wildlife trees within 10 m of the streambank by establishing safe work zones within the remainder of the management zone. Retain wildlife trees consistent with the section "Wildlife trees in the management zone."
- Fall and yard away.

Where the Best Management Practice cannot be achieved due to moderate or high windthrow hazard:

- Harvest windthrow-prone trees and maintain as many of the windfirm trees as possible, having the characteristics described in "Options to reduce windthrow risk in the management zone," within 10 m of the channel.
- Fall and yard away. Remove slash and debris inadvertently deposited in the stream at the time of harvest (see "Falling and yarding"). Where a shallow-rooted, wind-prone leaner is felled, fell the tree so that the butt clears the channel or the stem spans both streambanks. Remove only those stems that can be lifted without damage to the channel or bank. For those stems that cannot be lifted clear, leave the portion of the stem that spans the channel. Ensure the stem and limbs do not obstruct stream flow or fish passage.
- Retain wildlife trees consistent with the section "Wildlife trees in the management zone."
- Retain non-merchantable conifer trees, understory deciduous trees, shrubs, and herbaceous vegetation within 5 m of the channel to the fullest extent possible.

District _____
Cutting permit _____
Opening number _____
Year of logging _____
Crew _____
Date _____

Stream location
GPS location_____ Photo_____
☐ Open slopes
☐ Gully ___width ____ depth ___sidewall %
☐ Fan
☐ Valley flat

Stream stage dry low mid bankfull overbank

Channel type
☐ Bedrock
☐ Colluvial
☐ Step-pool
☐ Cascade pool
☐ Riffle pool
☐ Meandering
☐ Braided

Stream channel
_____ width
_____ depth
_____ gradient

Fish inventory
☐ Inventoried
☐ Default
☐ Observed **Species (if known)**_____
  ☐ Spawning
  ☐ Rearing
  ☐ Migratory

Sediment severity
☐ none apparent ☐ low ☐ moderate ☐ high

Sediment sources

☐ Tributaries	___ %
☐ Streambanks	___ %
☐ RMZ soil disturbance	___ %
☐ Landslides	___ %
☐ Roads	___ %
Total	**100 %**

Channel disturbance

Distance	Length of disturbance	Disturbance type	Severity			Photo
			L	M	H	
Total						

Total length of Moderate and High _____m

% of channel affected _____

CIV _____

	Low Impact					Moderate Impact			High Impact		
CIV	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
% Channel Impact	0	0.5	1	2	3	6	10	15	30	60	90

Overall Channel Assessment Rating _____

Comments:_____

_____

_____

Channel Disturbance Codes

Bed disturbance

- ☐ C1 Mid-channel bars, indicating sediment accumulation
- ☐ C2 Frequent fresh, even-aged, unvegetated bars (length/100m)
- ☐ C3 Homogeneous textures (fine or coarse) compared to natural template of heterogeneous sediment size distribution
- ☐ C4 Bar elevation higher than banks
- ☐ C5 Pool area decreased due to riffle crest erosion or due to depositional infilling
- ☐ C6 Pools infilled with sand or gravel
- ☐ C7 Mechanical scouring of the bed as a result of yarding (length/100 m)
- ☐ C8 Sluiced-out channel not attributable to a mass wasting event

Bank disturbance

- ☐ B1 Recently disturbed banks due to mechanical disturbance
- ☐ B2 Banks primarily evenly sloping as the channel erodes into the bed
- ☐ B3 Extensive bank erosion (absence of undercut banks) as coarse sediment is deposited overbank
- ☐ B4 Frequent fresh sediment sources along banks

In-stream wood characteristics

- ☐ D1 Debris jams infrequent and large compared to natural templates of frequent and small
- ☐ D2 Debris jams young and even-aged compared to natural template of distributed age classes
- ☐ D3 Frequent non-functional woody debris (parallel to flow or elevated above the banks)
- ☐ D4 Frequent accumulations of broken wood and slash; non-functional or in jams
- ☐ D5 Older LWD buried beneath recent sediment

Riparian

Silvicultural Prescription _____

SP reason for riparian harvest

- ☐ High windthrow risk
- ☐ Beetles
- ☐ Disease
- ☐ Harvesting constraints
- ☐ Timber values

Logging Method _____

Silvicultural System in inner 10 m

- ☐ Reserve
- ☐ Variable-width reserve
- ☐ Partial cut, single-tree selection
- ☐ Partial cut, non-merchantable retained
- ☐ Partial cut, group selection
- ☐ Clearcut

Tree Retention

LEFT:

0–5 m ____ % **5–10 m** ____ % **10–20 m** ____ % **20–30 m** ____ %

RIGHT:

0–5 m ____ % **5–10 m** ____ % **10–20 m** ____ % **20–30 m** ____ %

Tree count in 4-m-radius plot circles (four plots/100 m stream):

Tree diameter (dbh)	# standing			# windthrown		
	Coniferous	Deciduous	Dead	Instream	Out of stream	Area of sediment (m^2)
> 30 cm						
15–30 cm						
< 15 cm						

Number of windthrown trees/100 m _____ **Windthrow rating N, L, M, H**

Number of windthrown trees in channel _____

Number of streambank trees harvested/100 m _____

Loss of total canopy shade, at stream height

- ☐ Low
- ☐ Moderate
- ☐ High
- ☐ _____% shade loss

Loss of tree canopy shade

- ☐ Low
- ☐ Moderate
- ☐ High
- ☐ ____ % tree shade loss